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MATERIALS PROCESSING IN SPACE:
An Introduction to the G-480 Payload

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ABSTRACT

The Space Research and Development Organization (SRDO) at San Jose State University has designed and developed a small self-contained payload (designated G-480 by NASA) which will perform four materials science experiments in low-Earth orbit aboard the Space Shuttle. These experiments can be categorized under two areas of investigation - corrosion and electrodeposition. While none of these experiments have previously been performed in space, both government and industry have expressed great interest in these and related areas of materials processing and engineering. Immediately following a brief history of the G-480 project development, this paper will provide a description of each experiment followed by a tour of the G-480 payload. Expected results will also be discussed along with the function, design and operation of the payload hardware and software.

HISTORY

In May of 1983, San Jose State University (SJSU) received a donation of flight costs for a Get-Away Special (GAS) Payload from Aero-Auto Industries of Sunnyvale, California. This marked the beginning of SJSU's involvement in NASA's GAS Program and, in turn, the first GAS payload to be developed in Northern California. In January 1985, students representing the Schools of Engineering and Science gathered under the directorship of Dr. Robert N. Anderson of the Materials Engineering Department to develop a payload concept. By July of that same year, a Payload Accoomodations Requirement (PAR) had been submitted and signed by NASA. This followed two reiterations in which assistance was given by the GAS Project Office at Goddard Space Flight Center (GSFC) resulting in the timely development of a PAR which was concise and to the point.

By August of 1985, a preliminary Safety Data Package (SDP I) was drafted and submitted to NASA. The SDP I review identified that many possible hazards existed, most of which were attributable to a lack of information rather than to safety considerations. It became evident to us that, whereas the PAR represented a brief description of the payload concept and requirements, the SDP required specific detail on every aspect of the payload design and operation as well as ground operations supporting the flight activities. By the time the Final Safety Data Package (SDP II) was submitted in April 1986, the number of hazards were reduced and qualified. Currently, SRDO is involved in the final phase of its engineering and safety analyses known as "Phase Three" (SDP III) review with NASA; and nearing the payload hardware production phase. Extensive ground testing will commence early next year (1988) during which time the payload controller software will be debugged and experiment systems will be evaluated. G-480 Payload testing and integration will continue until the reactivation of regular STS flight activities.

EXPERIMENTS

BACKGROUND

I am often entertained by the looks I get from people who inquire about the types of experiments which we have selected to be flown in space. Often their reaction is that of surprise because they somehow expected something more than just electroplating and corroding objects in space. Although electrodeposition (or electroplating) is a very common industrial process and corrosion is a very common natural phenomena, both provide very interesting possibilities for space experiments. Unfortunately, many are simply accustomed to an 'Earthiy' perspective of things. This is understandable since most of us are native of this planet and expect things to be consistent everywhere else. Of course, we all know this isn't always the case because the exceptions are often well worth examining. It is easy to be trapped in a train of thought where we limit ourselves in terms of our 'Earthly' environment and, unconsciously, we include variables such as gravity ($9.8 m/sec^2$), the presence of air, orientation (up and down), thermal conductivity and many other things common to our environment. With the dawn of the space age, however, this can no longer be the case. GAS experimenters, in particular, need to discipline themselves with regard to these conditions. Such was the learning process that our organization encountered in the early days of its GAS project.

Prior to selecting our experiments, it was necessary to learn all that we could about the environment in which we would be operating. While we use the generic term 'space' to name the operating environment (anything above 50 nautical miles), it is more accurate to say low-Earth orbit (LEO). In fact, the Space Shuttle will never really leave the Earth's atmosphere. The Orbiter typically flies from 120 to 400 nautical miles in altitude which is confined within a layer of the atmosphere referred to as the ionosphere which is more so a dirty vacuum than air as we know it. One very interesting aspect is the presence of trace elements of oxygen in the ionosphere which will be discussed later on in this paper.

Fundamental problems regarding thermal flow and electromagnetic interference (EMI) were also noted. Lessons were learned involving the influence of gravity and that the term 0g is technically inaccurate (although still used generically to mean microgravity). As long as the Space Shuttle is orbiting the planet, it is still under the influence of gravity. While the Orbiter is in a constant state of free-fall, micro-gravity disturbances are generated through the use of maneuvering systems combined with other activities such as the motion of astronauts about the flight and mid-decks. All these things considered, our view of so called 'common' processes becomes quite interesting.

MATERIALS SPACE EXPOSURE TEST (MSET)

The largest and most visible of the G-480 experiments is the Materials Space Exposure Test (MSET). It consists of an Exposure Drum mounted in the window area of the GAS Motorized Door Assembly (MDA). This particular experiment is passive in the sense that it requires no other controls or initialization other than simply opening the MDA once on orbit. Operations in space have shown that ambient atomic oxygen presents a troublesome environment for organic, graphite and metallic surfaces. This has resulted in structural degradation and changes in thermal characteristics, reflectivity and conductivity. These changes are caused by high energy impact and chemical reactivity due to absorption of gaseous atoms on material surfaces. A sampling of select materials including various common metals, alloys, thin films and substrates will be flown in the configuration shown in Figure 1. Additionally, some materials will be galvanically coupled to examine the rate of corrosion between two dissimilar metals.

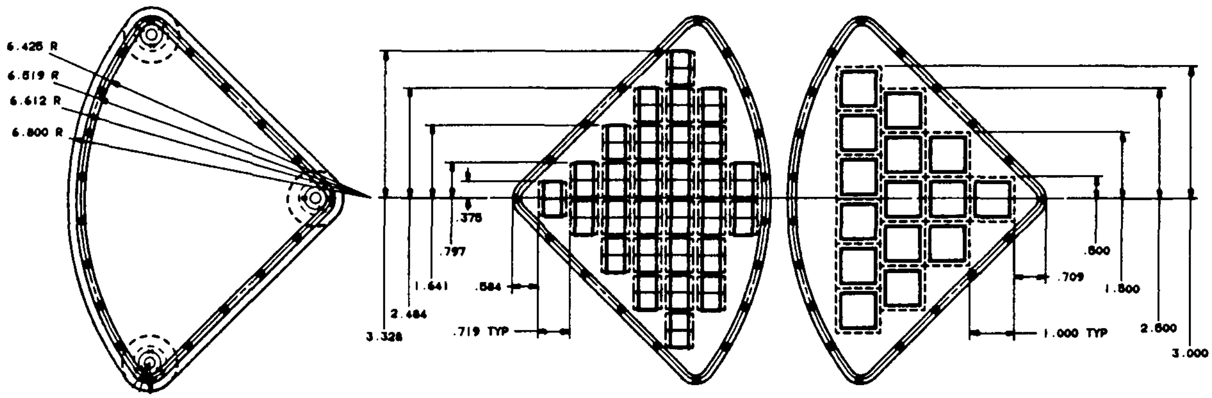

FIGURE 1

ELECTRODEPOSITION

The microgravity environment of space allows us to test electroplating techiques under conditions that are expected to produce unique physical, bonding and plating characteristics. Two experiments will test the effects of free-floating hydrogen molecules, produced during the plating process, on the structural matrices formed during low and high current density transfer of ions.

In the case involvng high current density plating, the quality of the plate is rather poor when performed on Earth. This process is often used in the production of powdered metals whereas ions, which are transferred from anode to cathode at a very high rate, fail to bond. When these ions adhere to the surface of the cathode they bridge out - ion upon ion. Under 1g conditions (Earth) these bridges collapse and become powdered metals. In a microgravity environment, these bridges should continue to grow undisturbed; thus, resulting in a structural matrices which will eventually support and reinforce itself. The low current density plating experiment will provide valuable insight in the production of a high quality surface plate in a microgravity environment. Figure 2 illustrates the test cell configuration of both electroplating experiments - low and high current density (left to right) respectively. The helix and the cube are the cathodes in these systems.

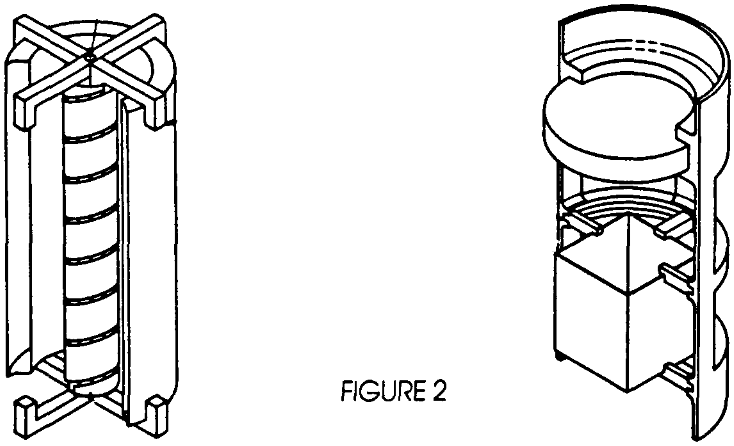

FIGURE 2

PITTING CORROSION

The formation of pits along the bottom, horizontal surfaces inside plumbing fixtures is attributed to the influence of gravity on sediments. These products build up and create a corrosive cap which initiates "pitting attack" or pitting corrosion. This experiment will examine the effects of induced pitting corrosion in a microgravity environment. The results of such tests have significant importance in design considerations of long-term space structures. Following the flight of G-480, the copper specimen used in this experiment will be cut and examined under a scanning electron microscope for pits and streaks. The ultimate goal in all of the pitting and exposure tests is to determine corrosion rates in microgravity environments. Figure 3 illustrates the development of pits on Earth and the configuration of the G-480 pitting specimen.

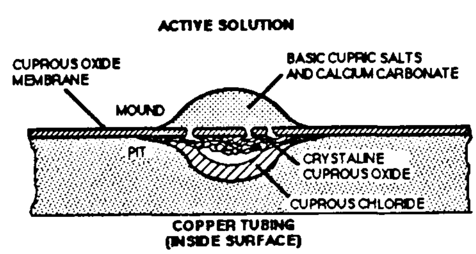

FIGURE A - Diagrammatic representation of the arrangement of corrosion products and of the reactions involved in pitting corrosion of copper.

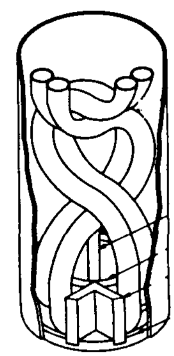

FIGURE 3

PAYLOAD

REQUIREMENTS

In addition to those requirements set forth by NASA, SRDO established further design specifications to improve the reliability and safety factors of the G-480 payload. A listing some of SRDO's design criteria are as follows:

1) All pressure vessels are contained within a secondary cell to provide a redundant level of protection in the event of leakage or cell burst.

2) Test cells are rated well above their expected pressures.

3) Prefer the use of space-qualified hardware.

4) The payload controller is programmed to monitor and control hazardous situations before they result in the shutdown of the entire system.

5) Thermal, electrical and EMI insulation.

6) All hardware has been designed to be reusable where possible.

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7) Special emphasis on simplicity in design. Reduce the number of mechanical parts where possible.

8) Testing of all individual components and the entire G-480 payload system prior to launch.

9) Surface mounted hardware, such as the exposure drum, is designed so that all bolts, nuts and miscellaneous small parts are mounted from the underside of the drum (within the canister).

10) All nuts and bolts will be safety wired where possible.

11) Back-up power supply for the computer to prevent loss of data and/or excessive drain on primary battery pack.

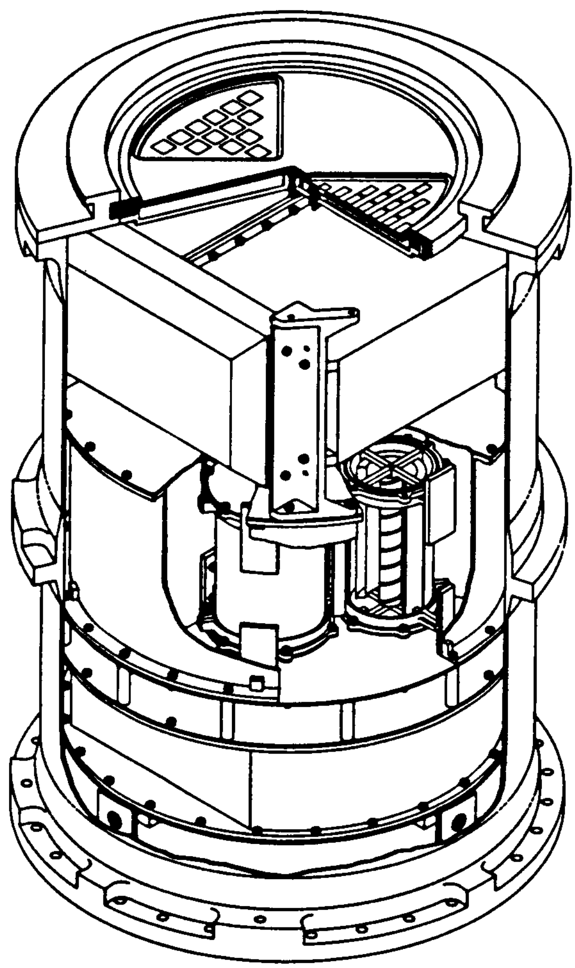

FIGURE 4

THE G-480 PAYLOAD

SPECIFICATIONS

As shown in Figure 4, the G-480 Payload will utilize the 5 cubic foot two hundred pound GAS canister with the Motorized Door Assembly option. By selecting to make use of the MDA, the overall payload weight becomes that much more critical due to a 40 pound penalty imposed with the use of the MDA. The following is a description of the G-480 Payload and refers to the cut-away drawing shown in Figure 4.

EXPOSURE DRUM

Atop the G-480 payload, mounted within the window area of the MDA and GAS endplate, is the Exposure Drum. Its most notable feature is the presence of two pie-shaped aperatures through which approximately 75 specimens will be exposed to the payload bay environment as part of MSET. Prior to the launch activities, the specimen trays are protected within the sealed exposure drum. As part of our final integration checklist, the specimen trays will be rotated into the aperature areas of the exposure drum at which time they will be protected by the sealed MDA.

POWER PLANT

Set between four structural post, which extend downward from the GAS endplate, is the battery box. It contains sixteen 25Amp-hour BC cell lead-acid batteries. Figure 5 illustrates the configuration of the left half of the battery box. The battery type and configuration are similar to that used in the AV-8 Harrier VTOL jet aircraft. Mounted to the battery box and between the two nearest structural posts is a switching power supply. This unit regulates all power requirements and contains a set of relays which will be used only in the event of pending emergency or as deemed necessary by the flight or ground crew.

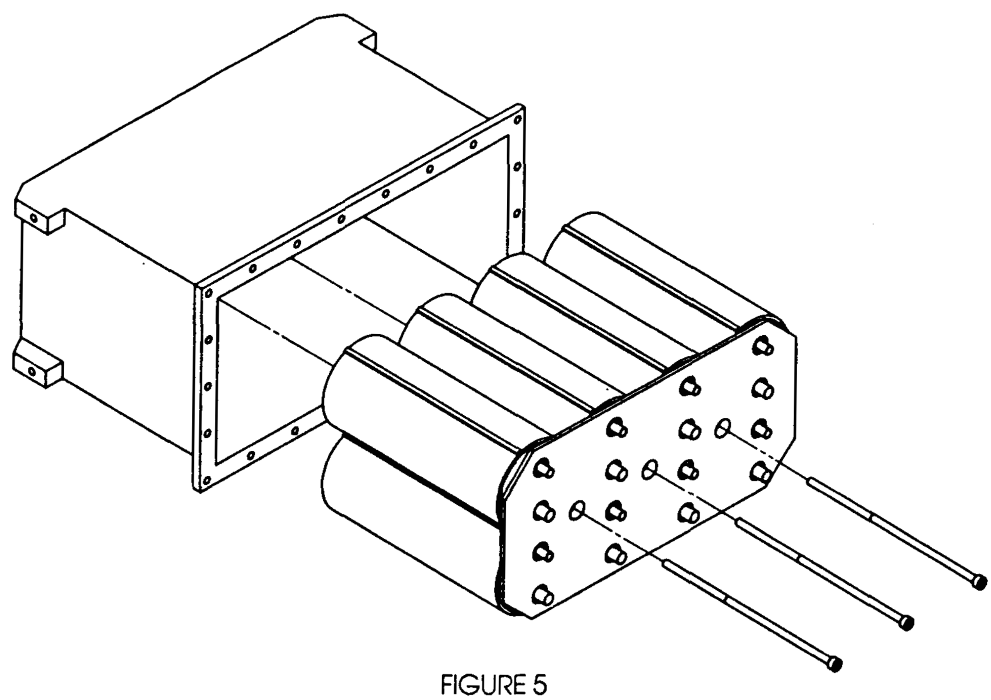

FIGURE 5

COMPONENT ENVELOPE

Centered in the G-480 Payload assembly is a large cylindrical container which we refer to as the Component Envelope. It contains all of the active experiments and serves as a secondary cell to limit

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hazardous conditions that could develop such as leakage of test cells. The component envelope is divided in to three equal sized compartments, each of which is capable of being pressurized. Within each compartment is an experiment test cell (ETC) and an adjoining reservoir which will contain electrolyte solutions for each specific experiment. Centered within this component is a triangular cable bay which provides us with access to power (above) and control (below). Figure 6 shows a top view of the component envelope and the subassemblies for the pitting corrosion and eletroplating experiments.

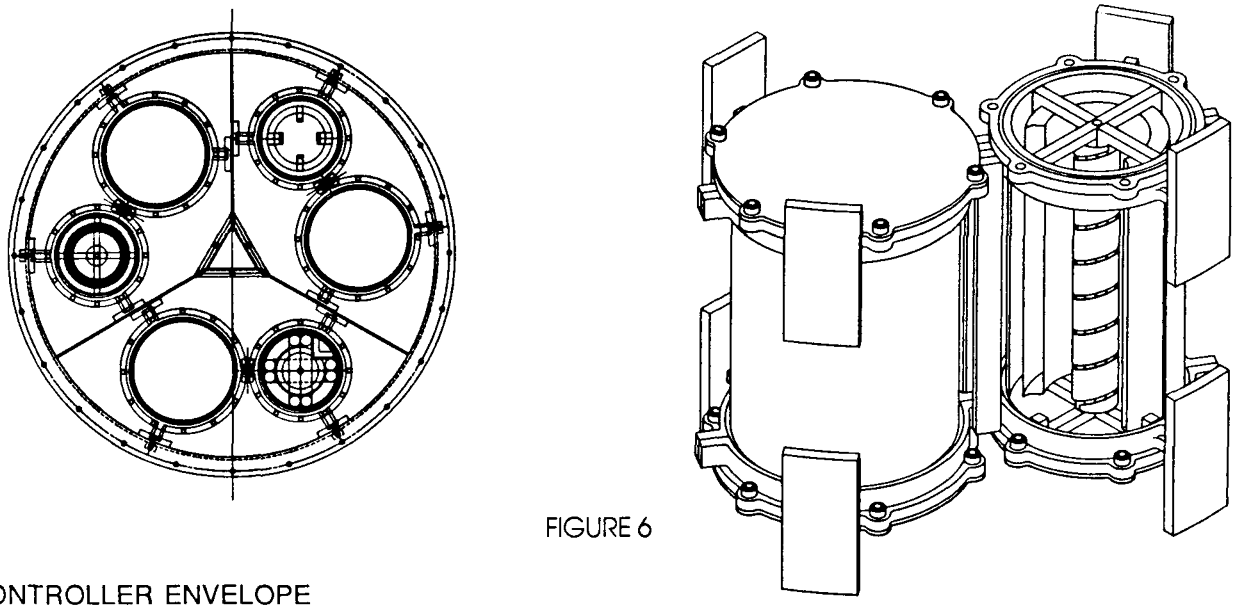

FIGURE 6

CONTROLLER ENVELOPE

At the base of the G-480 Payload is the Controller Envelope. This unit contains all data aquisition and control devices for the entire system. It is unique in that it also contains a battery back-up in the event of an unusually high discharge rate within the main payload battery system. This 16 bit payload controller consists of an 8086C processor (IBM compatible) and features: 1.2M bytes continuous memory, 192K bytes of ROM and a built-in clock. Originally designed for defense applications, this controller is very durable and has been tested for environmental conditions in excess of STS payload requirements. Software is currently in the early stages of development. We are evaluating several languages for use based on speed, reliability and programmer familiarity. The base of the payload is stabilized within the canister by four equally spaced lateral support bumpers.

OPERATIONS

Once the Space Shuttle has achieved orbit, the astronauts will activate relay A of the Autonomous Payload Controller (APC) resulting in the activation of G-480 and the opening of the MDA. The payload is programmed to begin house-keeping duties while preparing the experiments for operation. Shortly thereafter, the pitting corrosion experiment will be initiated. At a later time, just before a scheduled sleep period, the astronauts will activate relay B. This will initiate the electroplating experiments following a 1 to 2 hour wait. We do this because of past mission data which indicates that the least amount of microgravity disturbances take place during astronaut sleep periods. The deactivation of Relay B will indicate that the crew is preparing to complete inflight operations and return to Earth. All electroplating will cease and an inhibiting solution will be injected into the active pitting corrosion solution in order to slow down the corrosive process. The payload controller will then begin to shutdown each experiment, save the final data entries and prepare itself for reentry (i.e. the data storage unit has a retractable head). The deactivation of relay A will power down the G-480 Payload and close the MDA; thus, sealing the specimen materials involved in the exposure test until they can be examined in the lab.

CONCLUSION

It has been nearly three years now since we initiated the development of the G-480 Payload. We have done so with a core group of 5 people and many temporaries (those who work for about a semester or so). Most of us are full time students who have full or part time jobs on the side which only goes to show that GAS projects aren't just for professionals who dedicate the bulk of their time to a single program. Nonetheless, we have accomplished quite a bit and the benefits have been very rewarding. Local aerospace companies consider this to be one of the finest training experiences for those students who will go to work for them in the space industry. Many of the practical lessons have been learned here regarding the value of weight reduction and power conservation.

Whereas we were once pressed for ideas and payload concepts, we now have three on the 'back burner' and more under development. This progressiveness is not unique only to SRDO; other university programs and user group are experiencing the same influx of ideas because their people are now familiar with the GAS program, the Space Shuttle, and more importantly, its operating environment.

Of course, for those users who are just now getting started, a word of advise - be patient. We now enjoy a tremendous amount of support at the University level and in local industry involvement. This, needless to say, took a lot of work. Facilities are traditionally the hardest to aquire. Funding and staffing are also common headaches. The best vehicle, however, in realizing all these valuable things is to carry on with the paperwork. File your PAR and work your SDP through as far as you can take it. Eventually, you'll be holding the plans, signed paperwork from NASA and know what you're talking about when you approach companies and institutions. It really is not that difficult. In most cases, aerospace and other high tech companies have programs which promote such student activities. Ask not and receive not.

No one can be certain as to the results which our experiments may yield in space, nor the significance of the results. Perhaps this in itself is the most exciting aspect of Get-Away Special involvement. There are many opportunities to conduct experiments, both simple and complex, in space and do so for the first time ever. As more and more users make use of this vehicle that NASA has made available to us, I am certain that we will begin to see many more exciting developments and discoveries in time.

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